Marine Fouling and Boring Organisms at 100 Feet Depth in Open Water of Monterey Bay

BY

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(3 Figures, 2 Tables)

INTRODUCTION

Continuous studies on the fouling and boring organisms of Monterey Harbor and the open water of Monterey Bay down to depths of 50 feet have been underway since 1966. The initial results of these investigations have been published (Haderlie, 1968a; 1968b; 1969). In June, 1967, a study was initiated on the organisms that attach to or drill into test panels exposed to the marine environment of the open water of Monterey Bay at depths of 100 feet. The present paper summarizes the results of this investigation which extended over a 33 month period from June 1, 1967, to March 1, 1970. At the present time additional studies are being conducted at water depths of 200 feet and the results of these investigations will be reported in time.

As in previous studies, the primary objective of the investigation reported on here was to obtain information on the kinds of marine organisms that settle on or bore into test panels exposed to the marine environment. In addition it was hoped to learn something about the season or seasons of settlement, to determine preference for substrate, and to determine rate of growth and longevity of different organisms.

The author wishes to acknowledge the following colleagues for help in the identification of various fouling organisms: Mr. Jack Gougé (Foraminiferans); Dr. D. P. Abbott (Ascidians); Dr. Alan H. Cheetham and Mr. Robert W. Hinds (Ectoprocts). Acknowledgment is also due my wife, Mrs. A. E. Haderlie, for assistance in the laboratory work, and to Mr. J. C. Mellor and the various crew members of the Naval Postgraduate School's Hydrographic Research Vessel for arduous work at sea. The Naval Oceanographic Office and the Office of Naval Research provided financial support.

AREA of STUDY

The initial site chosen for this study was on the southern edge of the firing range approximately 1 nautical mile off Fort Ord in 100 feet of water (Figure 1). From the beginning it was apparent that swell and wave action would make it difficult to keep the arrays securely moored and in place. Monterey Bay is open to the Pacific and the area off Fort Ord receives the full impact of long period swell from the open ocean. None-the-less, it was possible to keep at least some arrays in place for a period of 9 months from June 1, 1967, until the end of February, 1968, when all except one array with Short Term panels attached were lost to storm waves. In anticipation of this difficulty, a new site was chosen in January, 1968, which was nearer the southern end of the Bay where some protection is afforded by the northerly projecting Monterey Peninsula. This new site was 1 nautical mile due north of Del Monte Beach in 100 feet of water (Figure 1). A complete set of arrays were planted off Del Monte immediately after the loss at the Fort Ord site occurred in late February, and a new series of collections began. There is, therefore, no break in the record of data. Although some losses due to winter storms were sustained, sufficient spare arrays were deployed at the Del Monte site to give continuous records for two full years.

The bottom of the Bay at both sites is sandy and relatively firm and flat. The water is clean and free of obvious pollutants. Due to lack of time and facilities, no physical parameters at the depth of the test panels were measured. For the first 20 months of the study surface temperatures were measured once a month at the test site and these varied from lows of 11.0° C recorded in December to highs of 16.0° C recorded in late summer and early fall. Previous studies in the southern end of the Bay (Bolin

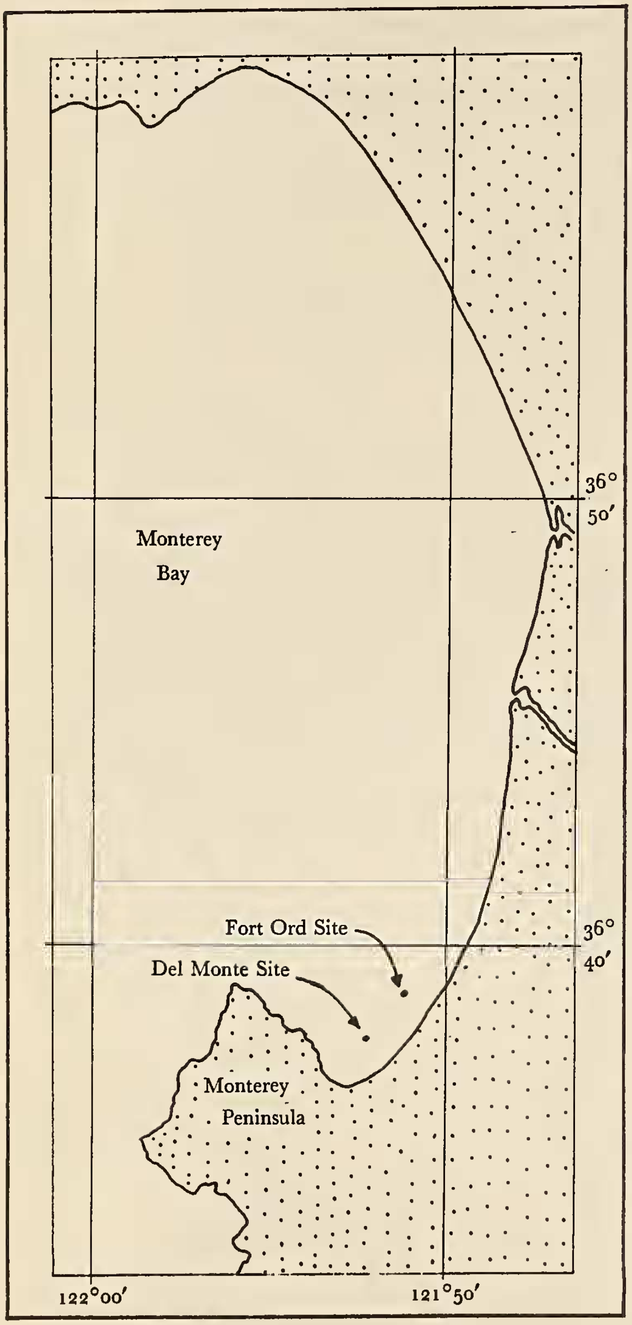


Figure 1

Map of Monterey Bay showing sites of fouling arrays off Fort Ord and Del Monte Beach

and Abbott, 1963) have shown that surface salinities are relatively constant during most years with averages ranging from 32.8 ‰ to 33.8 ‰. The tide at the sites of this study has a maximum range of 8 feet during springs and a mean range of 3.5 feet. Very little is known regarding current patterns in this part of the Bay, but the currents seem to be sluggish. Winter storms, however, can create considerable turbulence.

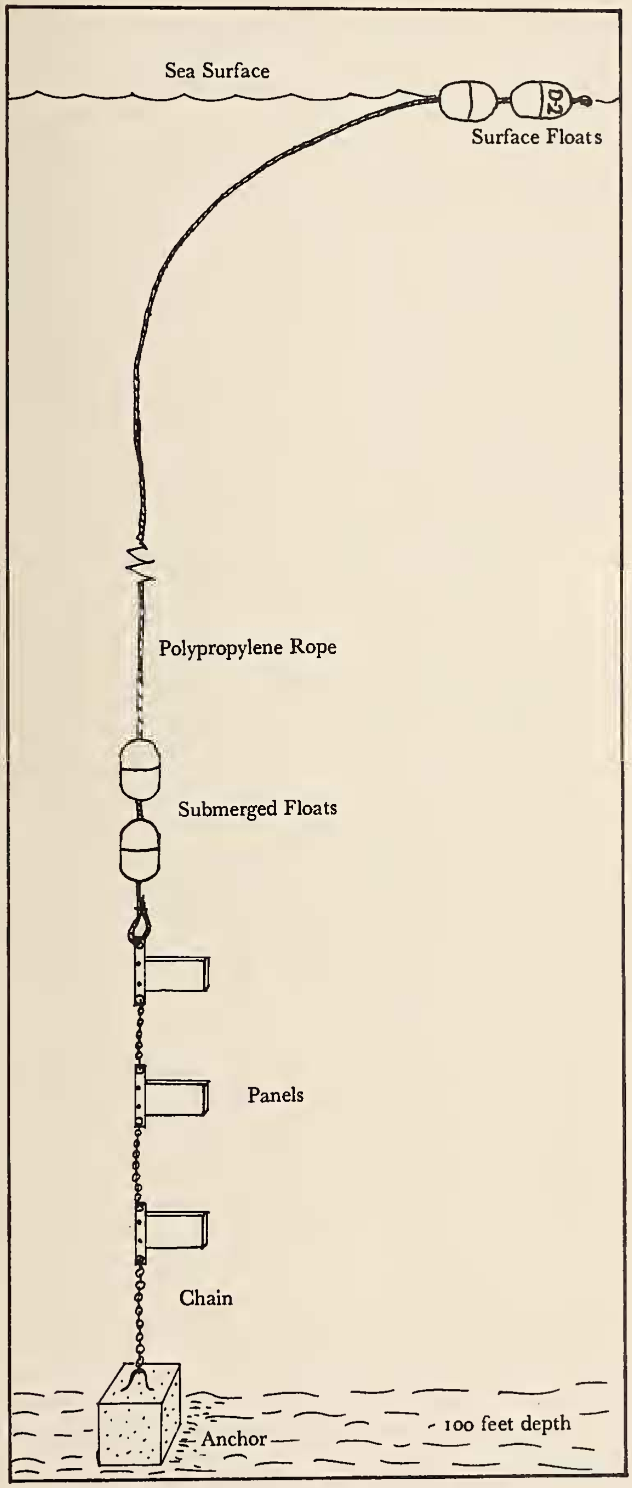
MATERIALS and METHODS

For many years the Naval Oceanographic Office has been conducting surveys of boring and fouling organisms in coastal waters of the world. In these studies standard test surfaces are employed at all sites so that results are comparable (De Palma, 1966). Similar test panels have been and are being employed in Monterey Bay.

In this investigation each test panel employed consisted of one piece of ¼ inch thick black asbestos board (Johns-Manville Colorlith) and one piece of ¾ inch thick flat sawn and planed douglas fir lumber. Each piece measured 6 inches by 12 inches and the two were attached back to back with brass screws. Previous studies by many workers have shown that black asbestos board is an effective collector of most fouling organisms. The wooden part of the test panel was employed primarily to collect wood boring organisms, but it also collected foulers and by comparing these with the population settling on the asbestos board it was possible to determine substrate preference for certain fouling organisms. These panels were of such size as to be handled easily in the field and the laboratory, yet were large enough to present a reasonable surface area for the settlement of organisms.

The panels were arrayed as shown in Figure 2. This arrangement was somewhat different from that employed previously (De Palma, 1966; Haderlie, 1968b) for in earlier work in Monterey Bay at the 50 foot level it was found that the polypropylene rope often failed at points of panel attachment due to abrasion and chafing. In the present study, therefore, the panels were not attached directly to the rope. On the end of each panel a bar of stainless steel measuring 8 inches × 1 inch × ¼ inch was secured with stainless steel bolts. This bar had holes in each of the ends. Panels were fastened together by shackles in this attachment bar and an 18 inch length of ¼ inch galvanized chain.

The mooring system consisted of an anchor made of a clump of concrete weighing 175 pounds in which a galvanized eye-bolt was embedded for securing the buoyant



array. From the anchor a 2 foot length of chain extended to the attachment bar of the lowest panel. In the work reported on here at depths of 100 feet, 3 panels were attached to each array. From a shackle on the attachment bar of the upper panel a ⅜ inch length of 3-strand black polypropylene rope extended upward to the water's surface. To keep the panels in a vertical orientation and to prevent their rubbing together, two plastic toggle floats (5 inches by 9 inches "Butyrate") were attached to the line immediately above the panels. These floats kept the panels vertical and the connecting chains taut, yet the panels were free to rotate and like flags could align themselves with the direction of water movement. The polypropylene rope above these bottom floats was slack and being slightly positively buoyant tended to float upward. At the upper end of the rope two additional toggle floats were secured and these were used for locating and recovering the arrays. Sufficient scope of rope was used to insure that the upper floats were not pulled under at high tide nor during normal wave action. Even if the upper floats were pulled under by an exceptionally high wave, however, the total buoyancy of the floats was insufficient to lift the heavy anchor off the bottom. The anchors on the arrays off Fort Ord were buried due to sand shifts and this made recovery of the arrays difficult and in a few cases impossible. Off Del Monte Beach this was never a problem. Most of the losses at both sites was due to corrosion weakening the chains or shackles which broke and allowed the arrays to drift away. The galvanized hardware, therefore, had to be replaced periodically, usually after about six months submergence. Some arrays were lost due to fishing vessels running over the floats at night and breaking them or cutting the polypropylene ropes. During the last two years of the project off Del Monte Beach a total of 18 arrays with 3 panels each were planted and 11 of these were recovered. Except for the loss of an array containing a panel that was meant to collect settlers during the month of November, 1967, the record of data for the entire 33 month period of study is continuous and unbroken.

Two series of test exposures were used in this investigation at 100 feet depth. Short Term panels were exposed on the first of every month and recovered the first of the following month for the entire period. These panels provided data on the season of settlement of different animals

(← adjacent column)

Figure 2

Sketch of fouling array

up to one month after settlement, and gave information on the nature of the pioneer fouling communities at dif- throughout the year, the rate of growth during periods ferent times of the year. A second series of panels called Long Term panels was exposed for one month and for cumulatively longer periods of time up to 12 months. The entire year-group of these panels was exposed at the same time; one was removed at the end of one month, a second at the end of two months, and so cumulatively up to 12 months. The Long Term panels exposed at the Fort Ord site remained in the water for a maximum of only 9 months (June, 1967, through February, 1968) before the arrays at this site were lost. At the Del Monte Beach site, however, panels exposed in March, 1968, remained in place for periods up to 12 months when a new series was planted that remained for up to another year until March 1, 1970.

Arrays used in this study were planted and recovered using a hydrographic winch on a 63 foot hydrographic research vessel. On the first of each month throughout the study period one of the arrays was lifted to the surface and appropriate panels removed. One month following the initial planting an array would be raised and one panel removed; this was used as the first of the Short Term panels, but also served as a one-month panel of the Long Term series. Before replanting the array a new Short Term panel was attached. At the beginning of the next month this Short Term panel was removed and another new one attached. At the same time a Long Term panel that had now been exposed for 2 months was removed. This routine of removing one Short Term panel and one Long Term panel and adding one new Short Term panel continued monthly throughout the year.

On raising the arrays the panels were out of the water for only a short time. Panels removed for study and laboratory analysis were immersed in a tub of sea water and were kept in sea water until the analysis in the laboratory was completed. As the panels were taken to the laboratory immediately after returning to port, the time involved from recovery at sea until analysis was begun rarely exceeded 2 hours. The animals on the panels were therefore all alive and active and this made analysis and identification much easier.

In the laboratory the panels were immersed in enamel pans full of cold sea water and the panel surface carefully surveyed with a binocular stereoscopic microscope ($\times 7$ to $\times 30$ magnification). This procedure made possible the discovery of small forms such as protozoans and the newly settled stages of barnacles and serpulid worms and the early stages of wood borers. This technique also made it possible to locate and identify many of the non-sedentary or loosely attached organisms that are often a characteristic part of the fouling community but which are often lost if panels are preserved in any way before they are analyzed. During the analysis of each panel, after identification of the foulers the numbers and size of each species were recorded. This procedure was carried out on both the asbestos and the wood surfaces. On the wood a special effort was made to search for evidence of wood borers. Following the analysis of each of the Long Term panels the asbestos side was scraped clean of all fouling growth and the scrapings were oven dried at 100° C until the weight was constant. The results are shown on the bottom line of Table 2 and are expressed as grams of dry weight of tissue and shell per panel side (0.5 sq. ft.). The amount of growth on the Short Term panels was usually so slight that this procedure of scraping and weighing was not carried out. The results of the weight analysis on the Long Term panels should provide a rough statistical measure of the concentration and size of organisms and an index to the productivity of the environment for the specific period of exposure. In practice, however, this is not possible, for on many of the panels exposed for several months it was obvious that the mass of barnacles, for example, had become so great that they had broken off in large slabs. In other cases most of the weight of the scraping was made up of the dead shells of barnacles that had been there for several months. In rough weather some of the fouling growth was accidentally broken off the panels during recovery operations. A combination of all these factors resulted in the rather meaningless weight figures given in Table 2, particularly for the older panels.

The wooden part of each test panel was not scraped but was dried and saved as a reference. In many of the older panels, however, there was little or no wood left due to the activities of wood borers.

At each 3 month interval, after the last panel was removed from an array, the entire array—floats, polypropylene rope, chain and anchor—was recovered and analyzed for the more obvious macroscopic fouling organisms. The upper floats after being in the water for several months usually carried heavy growths of a variety of algae such as *Polysiphonia acuminata* Gardner, 1927; *Ulva linza* Linnaeus, 1753; and *Enteromorpha* sp.; and were commonly fouled with the barnacle *Lepas anatifera* (Linnaeus, 1758). The upper parts of the polypropylene ropes also were fouled with the algae noted above but also often carried small specimens of *Macrocystis pyrifera* Agardh, 1820. The dominant fouling organisms on the ropes, however, were massive growths of *Obelia* sp. and the soft ectoproct *Bowerbankia gracillis* O'Donoghue, 1926. Associated with the organisms on the ropes were numerous nudibranchs, especially *Hermissenda crassicornis* (Eschscholtz, 1831) and *Dendronotus frondosus* (Ascanius, 1774) and skeleton shrimps (*Caprella californica* Stimpson, 1857). The lower floats were sometimes covered with the acorn barnacle *Balanus crenatus* Bruguière, 1789, and occasionally also carried a few specimens of the barnacle *Balanus tintinnabulum* (Linnaeus, 1758). Also commonly attached to the lower floats were sedentary polychaetes such as *Chitinopoma groenlandica* (Mörch, 1863) and the rock oyster *Pododesmus cepio* (Gray, 1850). The concrete anchors were all fouled with *Balanus crenatus* and *Chitinopoma groenlandica* and often carried dozens of nudibranchs, mainly *Acanthodoris brunnea* MacFarland, 1905.

THE FOULING COMMUNITY

1. Discussion of Organisms Settling on Short Term Panels and Substrate Preference

During the 33 months of this study a total of 28 different kinds of animals settled on or bored into the test panels exposed for monthly periods throughout the year at a depth of 100 feet (Table 1). This number of animal species settling is less than was found on panels exposed at 50 feet depth in an earlier study (Haderlie, 1968b) where 32 species were recorded. With the exception of two rare hydroids, no species were found settling at 100 feet depth that were not also found at 50 feet. As can be seen from Table 1 some organisms settled during practically every month of the year while others settled seasonally or rather erratically.

The dominant and most consistent foulers settling on the Short Term panels were serpulid worms (*Chitinopoma groenlandica*), acorn barnacles (*Balanus crenatus*), and hydroids (*Obelia* sp.). Other species were less abundant and encountered less frequently. The following discussion will review briefly the most common organisms of each major group listed in Table 1. Where there appears to be data supporting substrate preference these will be discussed also.

Protozoa:

The only protozoan that was regularly found on the one-month panels was the suctorian *Ephelota gemmipara*. This organism was commonly associated with the hydroid *Obelia* sp. where it attached to the perisarc of the hydroid colonies, but was also often found covering the shells of barnacles and also on the wooden and asbestos surfaces totally independent of other attached organisms. The colonial ciliate *Zoothamnium* sp. was seen only once, on a panel submerged during January, 1967. Foraminiferans were also rare on the Short Term panels.

Coelenterata:

Obelia sp. settled sporadically during most of the months of this investigation and often during late summer and early fall would be one of the dominant organisms on the Short Term panels. In a period of one month the colonies were usually not more than 1 cm tall, but on one panel submerged during August, 1967, the *Obelia* growth all over the panel was a dense mass with individual stalks being up to 5 cm tall. On a panel removed after being in the water during March, 1968, the lush growth of *Obelia* had gonangia filled with medusae. Other hydroids were encountered only rarely and usually in small numbers. One of these, *Clytia* sp., released masses of tiny medusae when the panel on which it was growing was removed to the laboratory after being submerged during June, 1967.

Platyhelminthes:

Two species of flatworms were recorded from these panels, but only *Notoplana acticola* was found on more than one occasion. As will be seen below, flatworms were more abundant and varied on the Long Term panels.

Ectoprocta:

Ectoprocts, which are the dominant fouling animals in Monterey Harbor, are much less common in deeper water of the Bay. Only one species was found to have settled on the Short Term panels at 100 feet depth, and this was found only once.

Annelida:

Although four species of annelids were recorded from the one-month panels, only *Chitinopoma groenlandica* was common and it proved to be one of the most consistent settlers observed. In earlier papers (Haderlie, 1969; Smith and Haderlie, 1969) this serpulid was referred to as *Chitinopoma occidentalis* (Bush, 1904). In a recent publication by Hartman (1969) this species is referred to as *Chitinopoma groenlandica* (Mörch, 1863) and will be so designated in this paper. Small specimens of *Chitinopoma* 2–3 mm long were found to have settled during most months of the year. December–February were periods of minimal settling. May–September seemed to be the months of maximum settling and often hundreds of small tubes up to 7 mm long could be found on a panel face.

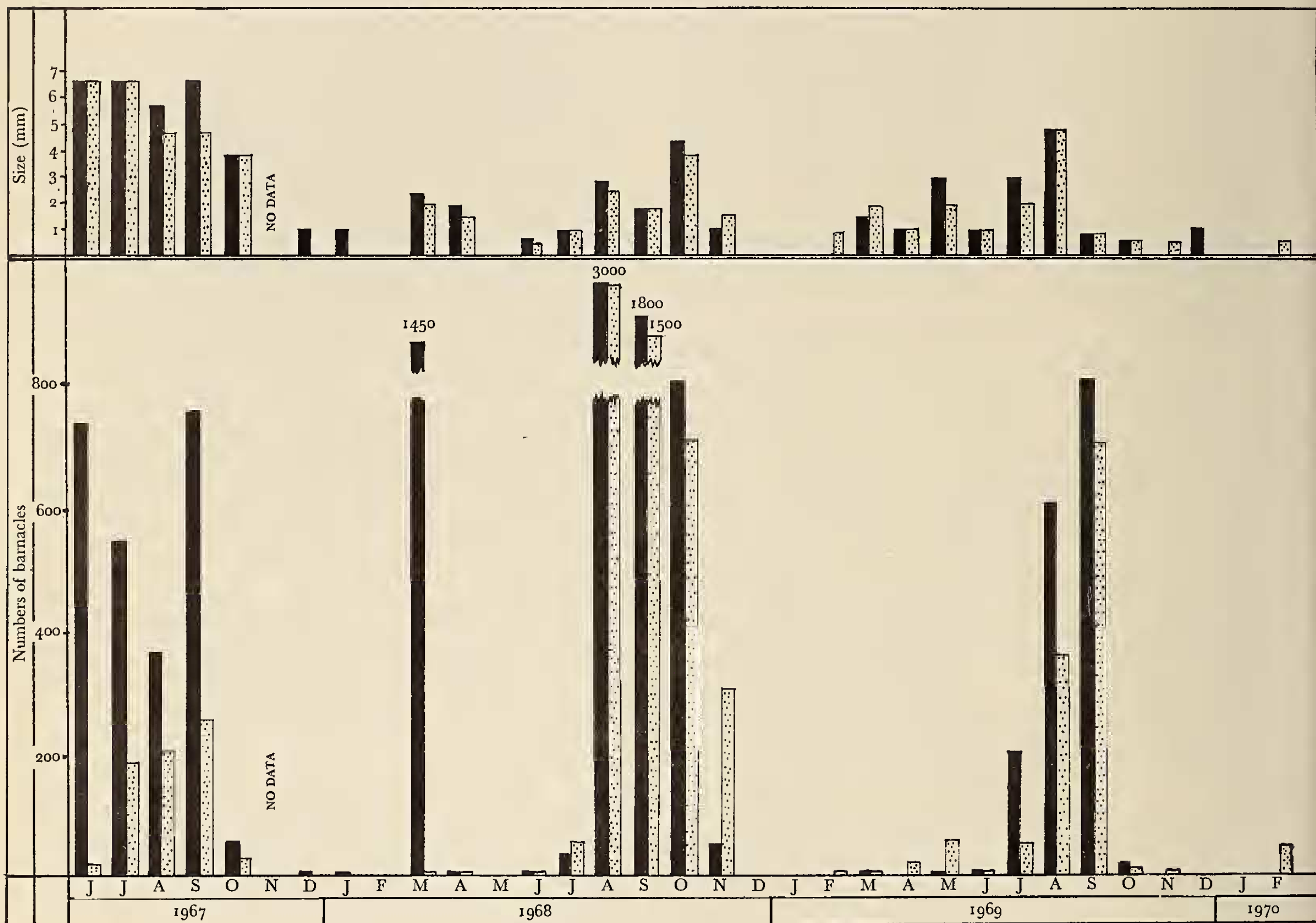


Figure 3

Numbers and sizes of *Balanus crenatus* settling on Short Term Panels

During September, 1968, *Chitinopoma* settled in numbers of 10/sq. inch on an asbestos panel. The worms seemed to prefer asbestos to wood as a settling surface, and on asbestos they showed no particular tube orientation. On the wood panels, however, the tubes were nearly all lined up with the grain of the wood.

Arthropoda:

Free-moving and tube-dwelling amphipods and an occasional small crab were seen on the Short Term panels,

Explanation to Table 1

Symbols used at head of columns indicate:

A = Asbestos board panel

W = Wooden panel

Symbols used in columns indicate:

1 = species present in numbers from 1 to 10 individuals or colonies per panel side

2 = species present in numbers from 11 to 20 individuals or colonies per panel side

3 = species present in numbers upward from 20 individuals or colonies per panel side

Species	1969																1970			
	May		June		July		Aug		Sept		Oct		Nov		Dec		Jan		Feb	
	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W
Protozoa:																				
Rosalina columbiensis (Cusl														1						
Ephelota gemmipara (Hartw	3	3	3	3	3	3	3	3			3	3	3	3						
Zoothamnium sp.																				
Coelenterata:																				
Clytia sp.																				
Hydractinia sp.																				
Syncoryne mirabilis (Agassiz																				
Obelia sp.					1	1	3	2		2	1				2	2				1
Platyhelminthes:																				
Notoplana acticola (Boone,																				
Pseudocerous sp.									1											
Ectoprocta:																				
Celleporella hyalina (Linna													1							
Annelida:																				
Chitinopoma groenlandica (	2	2	3	3	3	3	3	2	3	3	1	1	2	1				1		1
Platynereis agassizi (Ehlers,																				
Polydora brachycephala Ha									2											
Sabellaria cementarium Mo																				
Arthropoda:																				
Balanus crenatus Bruguière	1	3	1	1	3	3	3	3	3	3	2	2		1	1					3
Lepas anatifera (Linnaeus, 1																				1
Caprella californica Stimpsc													1			1				
Caprella sp.																				
Corophium insidiosum Cra																				
Loxhorynchus sp.																				
Mollusca:																				
Dendronotus albus MacFarl																				
Dendronotus frondosus (Asc																				
Hermissenda crassicornis (E							1	1												
Trinchesia albocrusta (Macl	1																			
Acanthodoris brunnea Macl					1		3	3	2											
Triopha grandis MacFarlan																				
Pododesmus cepio (Gray, 18																				
Bankia setacea (Tryon, 1863		1										3				3		3		3

Table 1

List of Species, and of Panels where Organisms Settled in Short Term Series

Species	1967 June		July		Aug		Sept		Oct		Nov		Dec	
	A	W	A	W	A	W	A	W	A	W	A	W	A	W
Protozoa:														
Rosalina columbiensis (Cushman, 1925)														
Ephelota gemmipara (Hertwig, 1876)					3	3	3	3	3	3			3	3
Zoothamnium sp.														
Coelenterata:														
Clytia sp.	3	3				1								
Hydractinia sp.					1	2								
Syncoryne mirabilis (Agassiz, 1862)														
Obelia sp.					3	3	3	3	2	2			2	2
Platyhelminthes:														
Notoplana acticola (Boone, 1929)			1				2		2	1				
Pseudoceros sp.														
Ectoprocta:														
Celleporella hyalina (Linnaeus, 1767)														
Annelida:											No data, panel lost	No data, panel lost		
Chitinopoma groenlandica (Mörch, 1863)	2		1		1		1	1	1					
Platynereis agassizi (Ehlers, 1868)			1											
Polydora brachycephala Hartman, 1936					1		3							
Sabellaria cementarium Moore, 1906													1	
Arthropoda:														
Balanus crenatus Bruguière, 1789	3	2	3	3	3	3	3	3	3	3			1	
Lepas anatifera (Linnaeus, 1758)														
Caprella californica Stimpson, 1857							2		3					
Caprella sp.			1											
Corophium insidiosum Crawford, 1937														
Loxorhynchus sp.			1		1									
Mollusca:														
Dendronotus albus MacFarland, 1966					2									
Dendronotus frondosus (Ascanius, 1774)	1				2	2								
Hermissenda crassicornis (Eschscholtz, 1831)			1	1	2	2	3		1					
Trinchesia albocrusta (MacFarland, 1966)					2	2				1				
Acanthodoris brunnea MacFarland, 1905					2	2			2	1				
Triopha grandis MacFarland, 1905														
Pododesmus cepio (Gray, 1850)			1		1		1			1				1
Bankia setacea (Tryon, 1863)														3

Species	1968 Jan		Feb		Mar		Apr		May		June		July		Aug		Sept		Oct		Nov		Dec	
	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W
Protozoa:																								
Rosalina columbiensis (Cushman, 1925)																								
Ephelota gemmipara (Hertwig, 1876)	3	3	3	3										2							3	3		
Zoothamnium sp.	3	3																						
Coelenterata:																								
Clytia sp.																								
Hydractinia sp.																								
Syncoryne mirabilis (Agassiz, 1862)																						1		
Obelia sp.					3	3	2				1	1	3	3	1	1						1		
Platyhelminthes:																								
Notoplana acticola (Boone, 1929)					1	1																		
Pseudoceros sp.																								
Ectoprocta:																								
Celleporella hyalina (Linnaeus, 1767)																								
Annelida:																								
Chitinopoma groenlandica (Mörch, 1863)					1		1	1	3	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2
Platynereis agassizi (Ehlers, 1868)																								
Polydora brachycephala Hartman, 1936																								
Sabellaria cementarium Moore, 1906																								
Arthropoda:																								
Balanus crenatus Bruguière, 1789	1				3	1	1	1			1	1	3	3	3	3	3	3	3	3	3	3		
Lepas anatifera (Linnaeus, 1758)																								
Caprella californica Stimpson, 1857																								
Caprella sp.																								
Corophium insidiosum Crawford, 1937																			3					
Loxorhynchus sp.																								
Mollusca:																								
Dendronotus albus MacFarland, 1966																								
Dendronotus frondosus (Ascanius, 1774)																								
Hermissenda crassicornis (Eschscholtz, 1831)																					1			1
Trinchesia albocrusta (MacFarland, 1966)																	1							
Acanthodoris brunnea MacFarland, 1905																			2	2				
Triopha grandis MacFarland, 1905																				1				
Pododesmus cepio (Gray, 1850)																								
Bankia setacea (Tryon, 1863)		2		3				1		2		2		1										2

Species	1969 Jan		Feb		Mar		Apr		May		June		July		Aug		Sept		Oct		Nov		Dec		1970 Jan		Feb	
	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W
Protozoa:																												
Rosalina columbiensis (Cushman, 1925)																						1						
Ephelota gemmipara (Hertwig, 1876)					3	3	3	3	3	3	3	3	3	3	3	3			3	3	3	3						
Zoothamnium sp.																												
Coelenterata:																												
Clytia sp.																												
Hydractinia sp.																												
Syncoryne mirabilis (Agassiz, 1862)																												
Obelia sp.					1		1	1					1	1	3	2		2	1				2	2				1
Platyhelminthes:																												
Notoplana acticola (Boone, 1929)																												
Pseudoceros sp.																	1											
Ectoprocta:																												
Celleporella hyalina (Linnaeus, 1767)																					1							
Annelida:																												
Chitinopoma groenlandica (Mörch, 1863)		1			2	1			2	2	3	3	3	3	3	2	3	3	1	1	2	1				1		1
Platynereis agassizi (Ehlers, 1868)																												
Polydora brachycephala Hartman, 1936																	2											
Sabellaria cementarium Moore, 1906																												
Arthropoda:																												
Balanus crenatus Bruguière, 1789				1	1	1	1	2	1	3	1	1	3	3	3	3	3	3	2	2		1	1					3
Lepas anatifera (Linnaeus, 1758)																												1
Caprella californica Stimpson, 1857																					1			1				
Caprella sp.																												
Corophium insidiosum Crawford, 1937																												
Loxorhynchus sp.																												
Mollusca:																												
Dendronotus albus MacFarland, 1966																												
Dendronotus frondosus (Ascanius, 1774)																												
Hermissenda crassicornis (Eschscholtz, 1831)	1						1								1	1												
Trinchesia albocrusta (MacFarland, 1966)					1	1			1																			
Acanthodoris brunnea MacFarland, 1905													1		3	3	2											
Triopha grandis MacFarland, 1905																												
Pododesmus cepio (Gray, 1850)																												
Bankia setacea (Tryon, 1863)		3				3				1										3				3		3		3

but the only arthropod encountered regularly was the acorn barnacle *Balanus crenatus*. In terms of numbers of individuals settling this species was clearly the dominant fouling organism at 100 feet depth. Small barnacles were seen on the panels during every month of the year at one time or another but, as can be seen in Table 1, January was clearly a period of minimal settling during most years and December and February were also low periods. Figure 3 presents these data in more detailed form and also shows the maximum size attained by the barnacles during any one month. The size recorded was that achieved at the time the panel was removed and depending on settling time the barnacles could be of any age from a few hours to one month. It appears, however, that *Balanus crenatus* can grow to a maximum size of 7 mm diameter in one month during the summer at 100 feet depth. During the summer months *Balanus crenatus* must grow most rapidly during the first few weeks or months, for the largest specimens ever observed on Long Term panels were 12 mm in diameter, and these were on panels exposed for 3 months from June 1 to September 1, 1967. Figure 3 also illustrates that periods of maximum settlement were also, in general, periods of maximum growth. Asbestos board was preferred to wood as a substrate in most cases, although exceptions exist. Also, maximum sizes achieved were, as a whole, greater on asbestos board than on wood. A curious exception to the above occurred in November, 1968, when 6 times as many barnacles settled on the wood as on the asbestos board and achieved a greater size on the wood.

During most of the time this study was in progress at the 100 foot level a similar study closer inshore at depths of 50 feet was also proceeding (HADERLIE, 1968b, and unpublished data). During any one month at the 50 foot level *Balanus crenatus* never achieved a size greater than 4.5 mm. It is also interesting to compare settling times at the two depths at sites that were only about ½ mile apart. In 1967 the maximum settlement period at 50 feet was during August (900 settled per panel surface), whereas in July and September far fewer settled (from 1–5 barnacles per panel surface) and in June none settled. One half mile further out in the Bay, however, at 100 feet depth, June and September were periods of maximum settlement (over 700 per panel surface) whereas August had about half this number. Another strange anomaly occurred in March, 1968. No barnacles settled on panels at 50 feet during the month, yet 1450 settled on the asbestos panel at 100 feet. In August, 1968, only 50 barnacles settled on a panel at 50 feet, yet 3000 settled on a similar panel at 100 feet.

The foregoing discussion illustrates the difficulty of predicting settling time and growth rates of fouling organisms when one has data for only a short period of time or from one depth. It is obvious that several years' data from various depths must be collected before the variations can be appreciated and predictions made.

Mollusca:

The only mollusks commonly encountered on the Short Term panels were a variety of nudibranchs. Of these *Hermissenda crassicornis* and *Acanthodoris brunnea* were the most abundant. A common boring mollusk (*Bankia setacea*) will be considered later.

2. Discussion of Organisms Settling on Long Term Panels

The Long Term panels which were exposed for cumulative periods of from 1 month to 12 months collected a greater variety of fouling organisms than the Short Term panels. A total of 57 species of animals identified at least to genus were recorded over a period of 33 months. Table 2 summarizes the data from the Long Term panels. Panels were initially exposed at the beginning of June, 1967, at the Fort Ord site and it was intended that they stay down for periods of up to one year. However, as explained earlier, after 9 months the arrays at this site were all lost and the first period of study of Long Term panels thus terminated on March 1, 1968. A new series was then exposed in 100 feet of water at the Del Monte Beach site and some of these remained in place for one year. A third series was exposed at the same site on March 1, 1969, and collected specimens for an additional full year.

Table 2 (bottom line) also presents data on the total biomass that collected on panels exposed for varying times. These data are not reliable as measures of total growth or productivity, however, for as the fouling growth increased in thickness the weight of the mass often caused slabs of growth to break away and be lost. This explains why the observed weight of fouling growth on one panel may be far less than that observed on a panel exposed for a shorter period of time.

As before, each of the major groups represented and the most abundant organisms within each group will be discussed.

Protozoa:

As in the case of the Short Term panels, the suctorian *Ephelota gemmipara* was the only protozoan regularly seen. It was most abundant on panels carrying a growth of *Obelia*, but was also seen independent of the hydroid, especially on the edges of the panels where it formed a fuzzy growth. A foraminiferan, *Rosalina columbiensis,* was seen only occasionally. This scarcity of benthic foraminiferans settling on panels in the open water of the Bay is in contrast to the relatively great numbers and varieties observed on panels exposed in the water of Monterey Harbor (HADERLIE, 1969).

Porifera:

The sponge *Leucosolenia eleanor* occurred only on panels that had been exposed for 6 months or longer, and occasionally formed large tangled masses of tubes. Two other sponges, *Leuconia heathi* and *Rhabdodermella nuttingi,* were of rare occurrence.

Coelenterata:

Obelia sp. was the only hydroid encountered regularly. It was exceedingly abundant on many panels and especially so on the polypropylene ropes that extended from the panels upward to the floats at the sea surface. Associated with the *Obelia* colonies were such organisms as the suctorian *Ephelotà gemmipara,* nudibranchs such as *Hermissenda crassicornis* and the skeleton shrimp *Caprella californica.* The gonangia on *Obelia* colonies were often full of medusae after exposures of one or two months.

On one occasion a single small sea anemone was found on one panel that had been exposed for 11 months. Although this animal was completely white in color it was obviously *Corynactis californica.*

Platyhelminthes:

At one time or another four different species of flatworms were encountered on the Long Term panels. Usually there were only a few worms per panel, but occasionally up to 20 could be found. Some of these, particularly *Pseudocerous* sp., were often found curled up in the larger dead shells of *Balanus crenatus,* and in general the greater the number of dead barnacles the greater the number of flatworms. Although no flatworm was seen feeding off a living barnacle, the possibility exists that such predation does occur.

Ectoprocta:

Bryozoans are the dominant fouling organisms in Monterey Harbor, but in the open waters of the Bay they are represented by fewer species and individual colonies. On the Long Term panels at 100 feet depth a total of 7 species was recorded but usually only one or two colonies were found on a single panel. Only in the case of *Tubulipora tuba* did numbers approach those found in the shallower water, and these appeared only on panels that had been submerged for several months. This species of *Tubulipora* was incorrectly identified and was called *Tubulipora pacifica* Robertson, 1910, in earlier papers dealing with fouling in Monterey Bay (HADERLIE, 1968a, 1968b, 1969; SMITH and HADERLIE, 1969).

Two additional species of bryozoans, *Phidolopora pacifica* and *Schizoporella unicornis,* were encountered quite often on older panels. In both cases the colonies of these forms were bright orange in color. These two have not been reported previously from fouling studies in shallower water of the Bay and harbor, but *Phidolopora,* at least, is well-known from natural rock outcrops on the bottom of Monterey Bay and is occasionally seen in deep, sheltered pools in the low intertidal.

Nemertea:

Nemertean worms are of infrequent occurrence on fouling panels at all depths in Monterey Bay. During the course of this study only 4 individual worms were encountered representing 2 species.

Annelida:

A total of nine species of polychaetes were encountered on the Long Term panels. Most of these were seen only occasionally, but three species were relatively common. *Chitinopoma groenlandica* was found on practically every panel examined and often in numbers in excess of 20 per panel. This was to be expected since these worms settle at 100 feet during most months of the year, apparently have relatively long individual life spans, and the calcareous tubes, once attached to a solid substrate, do not break off easily. On asbestos board panels in the water from March to July *Chitinopoma* with tubes up to 2 cm long were often the dominant fouling organisms. The mature

Explanation to Table 2

Date at head of double columns indicates time panel was removed from the water

Symbols used at head of columns indicate:

A = Asbestos board panel

W = Wooden panel

Symbols used in columns indicate:

1 = species present in numbers from 1 to 10 individuals or colonies per panel side

2 = species present in numbers from 11 to 20 individuals or colonies per panel side

3 = species present in numbers upward from 20 individuals or colonies per panel side